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Chapter

Use of Quality Potato Seeds in Family Farming Systems in the Highlands Zones of Peru

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Abstract

In the Andean region of Peru, the predominant production system for potatoes is family farming, oriented towards self-consumption, seed provision, and the sale of surplus production. Labor force activities for land preparation, sowing, maintenance, harvest and postharvest are under the responsibility of the family and eventually they hire farm laborers, when parcels are of a considerable size. Approximately 95% of the cultivated surface of potato crops is located in the high Andean zone, from 3000 to 4200 meters above sea level (masl), employing native varieties of tuber seeds and modern seeds introduced to production systems in the past 50 years. Potato systems in Peru, like the majority of underdeveloped countries, are characterized by the co-existence of formal and informal systems. Formal systems prioritize production and commercialization of seeds of just a few varieties positioned in modern markets which are regulated and accredited by a certification body according to the current legislation, while in the informal system the guarantee of seed quality falls under the responsibility of the very producers and users of those seeds.

Keywords: certified seed, family farming, seed regulation, *Solanum tuberosum*, traditional seed

1. Introduction

Peru is considered to be a center of origin and diversity of edible food species, and among them the potato (*Solanum tuberosum* L), a crop initially domesticated in the northern area of Lake Titicaca where among wild species the first cultivated forms were selected 7,000–10,000 years AD [1–4]. According to the International Potato Center (CIP), in Peru there can be found nine cultivated species of potatoes that originate from wild species of the group with *S. candolleanum* as a potential ancestor [5]. Other studies indicate that, in the Peruvian Andes 8 cultivated species can be found and around 200 wild species, which give rise to a large diversity of cultivated species included in polyploid series (2n = 24, 36, 48, and 60) with approximately 4200 varieties or morphotypes of native potatoes, recognized worldwide for their high nutritional value and potential for genetic improvement [4, 6, 7].

Starting in the second half of the 16th century, the Spanish began a process of world expansion of potato cultivation. Initially the first tubers were brought

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from Peru to the Canary Islands and thereafter to Spain, the United Kingdom, the Netherlands, India, Ethiopia, and Saudi Arabia [6]. Currently the potato on a global level is the crop with the fourth largest cultivated surface area after maize, wheat and rice, and therefore, forms a critical part of the global food system [8, 9]. In the high Andean zone in Peru, for the majority of farmers, the potato continues to be a basic food crop and is produced through traditional techniques such as the use of numerous different varieties and cultivated species with different spatial and temporal distribution.

It is the main transitory crop with approximately 367,000 ha of area planted, directly involving 710,000 families [6–8, 10, 11]. They are grown from sea level to 4200 meters above sea level depending on the adaptation of the varieties, the production system (traditional or conventional) and the destination of production for self-consumption or sale to the market [6, 12]. Modern varieties such as INIA 303 Canchan and UNICA adapt very well to the agro climatic conditions of the coast and were 'Andeanized' or adapted by family farming and they are cultivated from sea level, in the inter-Andean valleys and part of the plateau up to 3800 meters above sea level. The native varieties of various cultivated species are sown under the rainfall regime of 3,500 to 3800 meters above sea level, and bitter varieties of the species *S.* X *juzepczukii* y *S.* x *curtilobum* from 3800 to 4200 meters above sea level.

According to data from the last National Agricultural Census (CENAGRO-2012), family farming represents 97% of the more than 2.2 million agricultural units (AU), concentrated mainly in the Sierra region [13]. According to the Encuesta Nacional de Hogares (ENAHO - National Household Survey), Family Farming (FF) generates about 80% of the food products consumed in the national market. In order to recognize and strengthen small famers in rural areas, the government promulgated the Estrategia Nacional de Agricultura Familiar (ENAF- National Strategy for Family Farming); however, it does not include plans for the sustainability of potato cultivation based on genetic and ecological potential, to favor access and use of quality seeds, ENAF-2015 [14].

Other temporary interventions were implemented by some non-governmental organizations (NGOs), international technical cooperation organizations, the church and local governments; the most notable being Semillas Andinas (Andean Seeds) implemented by MINAGRI and FAO between 2011 and 2016. The project, with a high component of capacity building in seed technology, legislation and business plans, managed to overcome paradigms that small farmers would not be able to produce high quality certified seed. Family farmer system producer organizations that were trained in the production and use of quality seed through the field school methodology (ECA), managed to increase potato crop yields by 64%, exceeding the national average [15]. However, failure to follow-up by the agricultural sector and the lack of strategies for the continuity of successful models impeded the consolidation and autonomy of seed producing organizations [10, 11, 15].

Various studies carried out on the sustainability of potato cultivation in the high Andean zone agree that the use of low-quality seeds is the main factor that explains the low yields [15, 16]. For the year 2018, the national average yield was 15.76 t/ha; while, at the level of small farmers in the High Andean zone, yields are below 8; considering that almost all potato production is located in the Sierra (90%) it deserves immediate attention [8]. This situation is less overwhelming for potato producers in Latin American countries such as Argentina, Brazil, Colombia, Chile and Venezuela, which reach average yields of 20.86 t/ha. These differences may be due to environmental conditions, technology, management, but are mainly due to the use of quality seed [6, 8].

Much of the yield gap that currently limits productivity in low-income countries is attributed to poor seed quality. The availability, access and use of quality seeds of adaptable crop varieties are of vital importance to improve agricultural productivity, ensure food security and improve farmers' livelihoods. However, despite the advances in research and development of varieties, the rate of use of quality seed is low in traditional systems [9].

Formal systems promote the production and use of certified seed, generally of modern or hybrid varieties, preferred in conventional production systems that use external inputs such as pesticides, fertilizers and intensive soil tillage. Likewise, this system is governed by seed legislation supervised by the seed authority in charge of public entities. On the other hand, informal potato seed systems use native seeds or the so-called local, artisanal or 'personal seeds', with an ancestral dynamic such as the exchange of seeds, seed production in high areas to reduce the risk of virus infection and, therefore, for various reasons, they often produce relatively high quality seeds. The informal seed system can be complex; however, there are many links between the two prevalent systems in Peru [9, 11].

The coexistence of formal and informal seed systems is evident in the case of potato cultivation, which began with the enactment of the Ley General de Semillas (LGS- General Seed Law) in order to promote research, production, marketing and the use of quality seeds. The LGS regulations prioritize the production and commercialization of certified seeds with a clear objective of formalizing all seed production; however, in the last 30 years the rate of use of certified potato seed has not exceeded 1%. Consequently, this process has favored technology transfer processes, including the introduction of modern potato varieties that were adopted with relative success in family farming systems.

Family farming can contribute significantly to the development of the formal seed sector, not only in increasing the rate of use of certified seed, but also in the production of seed of native and modern varieties [10, 15]. However, the sustainability of the system will depend on a favorable environment, based on adequate seed legislation, efficient services, technical assistance, training, and technology transfer both at the level of producers and seed users [11, 15].

2. Family farming systems

Family farming is of high importance for food security, generation of agricultural employment, poverty alleviation, conservation of biodiversity and cultural traditions of communities in Latin America and throughout the world [10]. They are agricultural holdings with a predominance of use of the family labor force, where the administration of the economic-productive unit is assigned to the head of the household [17]. Another distinctive characteristic of other forms of agriculture is the limited access to land, water and capital resources; multiple-income survival strategy and heterogeneity [14].

Unlike other production systems, family farming presents a high degree of flexibility, dedicating efforts to work according to the situation and especially according to market prices. The management of production systems using the logic of crop diversification allows this flexibility, and is a factor that contributes to the economic stability of the sector. Likewise, it includes on-farm and off-farm activities (temporary work on other farms, mining and other activities), generating economic income in rural or urban areas. These activities are carried out in dynamic interrelation with the social, economic, cultural and environmental circumstances. Hence, it is inseparable from the family production unit, since it has the same resources at its disposal, and decisions about employment influence both in the family and the productive unit.

In family farming, the size of the farm and/or agricultural production is a determining factor for its classification [14, 17]. This classification includes subsistence family farming, families without land and family farmers fulfilling existing demand and generating surpluses. Family Farming (**Table 1**), depending on its land resources, cultivated area, technology and access to the market, can be classified as Subsistence Family Farming (SFF), intermediate or transitional Family Farming (IFF) or Consolidated Family Farming (CFF).

2.1 Potato cultivation in high Andean production systems

Peru is considered one of the main centers of genetic diversity and variability of cultivated and wild potato species and it is known that an intensive process of

Variable	Subsistence family farming	Intermediate family farming	Consolidated family farming
Production system	Traditional, use of supplies and local technology	Mixed production system: traditional and conventional	Conventional production
Farming system	Diversified crops, more than two crops in one plot and more than two species per crop	Monoculture, one variety	Single crop monoculture
Workforce	Family or community	Family and local farmers	Local laborers contractors or from other localities
Type of exploitation	(150–200 wages/ha)	80–120 wages/ha	60–100 wages/ha
Water dependency	Under temporary regime, it depends on rains	Temporary regime and irrigation	Temporary regime and irrigation
Seed system	Informal, the use of traditional seed	Informal/formal	Formal
Environmental conditions	Vulnerability to water extremes (drought, frost, hail or excess of rain)	Variable but less adverse conditions	Variable but less adverse conditions
Seed use	Native; wide variability available, “mixed sowing” (Chagro, Huachuy)	Native and modern selected by market demand	Native and modern selected by market demand, urban distributors, or processing companies
Type of Production and exploitation of land	Smallholding, planting area less than 1 ha	Small and medium farmers of 1 to 4 ha	Medium to large farmers from 10 to 150 ha
Efficiency	2–10 t / ha (extremes from 0 to 15 t / ha)	15–25 t / ha (extremes from 8 to 30 t / ha)	20–35 t / ha (extremes from 10 to 50 t / ha)
Market	Far from urban centers or markets	Medium proximity to urban centers or markets	Close proximity to urban markets
Cost of production	US $ 600–1200 / ha	US $ 1500–2500 / ha	US $ 3000–4500 / ha
Endpoints production	Production for self-consumption, exchange and less than 20% sale to the market	80% to the market	To the market (100%)

Table 1.
Characteristics of family farming potato production systems and their relationship with seed production and use.

domestication of cultivated species took place from species that gave rise to various potato morphotypes called native varieties that are characterized by their various shapes, colors, and size. Archeological remains suggest that Pre-Columbian and Inca cultures were possibly those that contributed to selecting and developing the cultivated species that are currently known. Among the species cultivated in Peru are; *Solanum tuberosum sp. andigena*, *Solanum goniocalyx*, *Solanum stenotomum*, *Solanum x chaucha*, *Solanum x ajanhuiri*, *Solanum x juzepczuki*. As a result, farmers have a great diversity of potatoes that contribute to their resilience and food security strategies. For example, the diversified multi-variety planting with more than two cultivated species of potato in a single plot in the high Andean zone called Chaqro, is a strategy that allows them to manage and mitigate the effects of climatic risks such as frost or the incidence of pests and play an important role in the in-situ conservation of native potato diversity [18].

According to the national agricultural census carried out in 2012 (CENAGRO-2012), in Peru there are approximately 2,160,000 farmers, of which 90% have less than 10 ha and correspond to the category of small and medium farmers [13]. In the case of the high Andean zone of Peru, the average landholding per family is 0.80 ha where small farmers, especially traditional ones, practice diversified agriculture with potato crops as head crops, corn (*Zea mays* L.), wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), broad bean (*Vicia faba* L.), tarwi (*Lupinus mutabilis* Sweet) and some vegetables [17, 19, 20]. Potato cultivation in Peru generates permanent work for approximately 710,000 families with 33 million daily wages in all tasks and production activities, harvest and post-harvest.

Potato production generates approximately, a corresponding demand for 4.5 million tons of seed tubers annually, thus constituting an important activity in the generation of income and the basis of their food security [6]. The average per capita consumption is 90 kg/person/year and continues with a growing trend despite the introduction of other foods, both those from government social programs and the flow of industrialized or processed products that are gradually causing changes in the rural communities diet [18].

3. Seed systems in potato cultivation

Seeds are the principal input of agriculture, regardless of the production system, the technology used, and the end product point. Consequently, the supply of seeds is a function of the predominant seed systems in a region where formal systems (certified seeds) and informal systems (non-certified seeds) coexist. Various actors from public and private institutions, producer organizations, plant breeders, service providers, technical assistants, agricultural innovation centers and universities participate in both systems; likewise, commercial potato and seed producers and traders. Seed inspectors also participate in the certification, supervision, marketing and distribution of seeds [3, 20, 15].

The coexistence of informal and formal systems is unavoidable and possibly the same actors participate in both systems; however, each has its own characteristics. Formal systems produce and use generally modern certified seed from conventional production systems (**Figure 1**); it typically works for a limited sector of farmers [3, 21]. In contrast, informal potato seed systems use native seeds or so-called local, artisanal or personal seeds, with a natural dynamic such as the exchange of seeds that dates back several centuries and, for various reasons, often produces quality seeds. Although the informal seed system is complex, there are many links between the two systems [9, 11, 22].

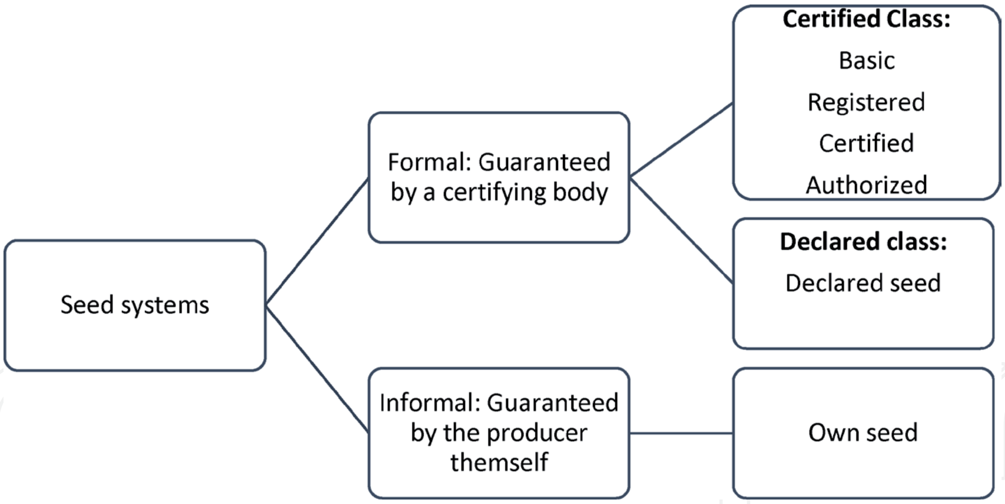

Figure 1.
Potato seed systems.

Family farming contributes significantly to the production of both certified and non-certified seeds; Currently, modern varieties are registered in the national registry of commercial cultivars, as well as native varieties with greater demand in the national market, which may be subject to certification [15].

3.1 Access to seeds categorized as higher quality

The production of elite seeds such as pre-basic and basic potato is in the charge of public and private institutions that have infrastructure and laboratories for the accelerated multiplication of potato cultivars with the highest demand in the market. Generally, the maintenance and management of a seed program has high costs because it is a highly specialized activity. In many developing countries, these functions are often performed by public sector breeding programs [10, 11, 15]. Consequently, the sustainability of certified seed production in family farming systems is weak, because it is almost impossible to maintain improvement programs with their own resources that do not allow them to access new varieties and/or produce seeds of higher categories (genetic, basic or registered).

For this reason, the producers of seeds of certified, authorized and declared categories depend on the operational and logistical capacity of the institutions or companies that produce the pre-basic and basic seeds. Delays in the availability of adequate quantity and quality of seeds can cause large bottlenecks in the production of quality seeds. Therefore, it is necessary to promote the establishment of agreements or contracts between seed producer organizations and public improvement programs that establish commitments to deliver seeds with quantity, quality and punctuality [10]. Likewise, it is necessary to strengthen the capacities of producers and users of quality seeds with training methodologies where knowledge is gained through participatory and experiential practices.

3.2 Seed quality in family farming systems

Four key characteristics have a big impact on the quality of the harvest of a potato field: physiological age, genetic purity of the seed, size and phytosanitary appearance of the seed [6, 23]. When referring to seed tubers, in the case of high Andean farmers, quality refers to the level of response of the seed to adverse agro-climatic situations. When a local variety does not respond to the expectations of the farmer who uses the seed, distrust of the seed producer begins and it is classified as poor quality or degenerate and is generally discarded. Potato degeneration is the main cause of reduction in yield or quality caused by accumulation of pathogens and pests in planting material due to successive cycles of vegetative propagation and it has been a long-standing production challenge for farmers and potato growers around the world [24]. In the Andes, seed degeneration caused by virus infection is much slower at altitudes greater than 2800 masl and even more reduced at altitudes greater than 3500 masl [6, 25].

Native cultivars managed by high Andean farmers have been maintained for several years with relatively low rates of disease spread. This is supported by studies carried out in traditional Andean potato seed systems during the last 30 years; they often found relatively low frequencies of virus-infected tubers limiting yield [6]. Farmers maintain local knowledge to define whether a seed is of quality or not; among them, knowledge of the phytosanitary status by verifying the presence of pest insects such as the Andean weevil (*Premnotryphes spp*.) that damage seed tubers; fungal diseases such as wart (*Synchytrium endobioticum*), powdery scab (*Spongospora subterranea*); and bacteria such as potato smut (*Tecaphora solani*) or blackleg (*Pectobacterium ssp*.) and finally the discoloration or dwarfism caused by viruses [16]. When farmers observe tuber deformations, they associate that the seed is tired, degenerated or aged, due to the use of a batch of seeds for several planting seasons, generally for more than five years [24].

Factors such as genetic material, agronomic management and cultural practices contribute to maintaining the quality of potato seed in the informal systems of the Andes. Agricultural practices, location of seed production fields at high altitudes, types of tillage, crop rotation, diversified planting, sectoral management and the number and height of hills are factors which can reduce the phases of diseases transmitted in the soil leading to degeneration of seed tubers [6, 26]. Other intrinsic factors of each variety such as resistance to Potato virus Y (PVY) and Potato leafroll virus (PLRV) in *S. tuberosum* ssp. *andigena* may contribute to reducing the spread of these diseases between plants or their replication within plants [6, 25].

3.3 Perception of the concept of quality seeds in the informal sector

In informal sector seed production systems, perceptions of seed quality differ from those of formal system farmers; while farmers who use their own seed rate their seeds as good, bad or fair, farmers with formal systems trust some certifying body that guarantees the quality of the seeds [3, 15]. Farmers in the high Andean areas associate quality through color, shape, size and the presence or absence of deformations in the tubers [16, 27].

Currently, with the introduction of modern varieties, this can be observed in rural communities, where good farmers are those who meet the minimum requirements for quality seed production. In the perception of quality, small farmers in the Andean highlands prioritize personal values such as safety, health and well-being and based on this logic they prefer seed tubers that reflect the characteristics of the variety in combination with seed quality signals that reflect altitude, soil and low input management and do not associate the latter with tuber seeds from the formal seed sector [28]. Seed certification cards do not substitute for perceptions of quality that farmers have learned to use and seeds they trust for generations.

A very important aspect is the leading role played by women in family farming systems in the management of agricultural units. They are not only responsible for family care and feeding the children but also for the maintenance of basic resources for family food security. Women play a key role in maintaining the genetic diversity of potatoes, particularly in the seed selection stages of the complex varieties, storage and planning of future plantings [15, 29, 30]. In the higher altitudes of Andes of Peru and Bolivia, women act as conservationists preserving the greatest possible diversity of bitter potatoes (*Solanum Jueepczukii* and *S. curtilobum*) that can be grown at temperatures as low as −3°C and can be dried to obtain traditional products such as *chuño* and *moraya* consisting of frozen, dried and dehydrated potatoes.

The selection of seeds of the native varieties is carried out based on the morphological interpretation and the in-situ yield of the crops, the culinary quality, the crop yield, the quality of the processing and the resistance to diseases, drought or flood. Consequently, controlling genetic diversity through careful management of variety and combinations allows communities to manage risks, particularly where climatic stress is more frequent and intense.

3.4 Certified seed potato production in the formal system

The production of certified seeds starts from *in vitro* seedlings with origins fully proven under specific production guidelines or standards and these stocks move through a series of steps following clear regulations and result in high-quality certified seeds [6, 31]. The aforementioned procedure includes the production of virus-free seedlings for both native and modern cultivars. However, the exclusion from the registry of commercial cultivars of other native varieties with high potential in quality and yield are limiting in the development of the seed system in the high Andean zone; this may influence the fact that a lack of virus cleaning in relegated varieties can result in low yields and low profitability [11].

In Peru, rice, cotton and hard yellow corn crops have the highest rate of use of certified seed; while, for crops such as potatoes and starchy maize, the seed use rate does not exceed 1% [8]. Therefore, it is explained that formal systems respond to the expectations of large commercial farmers and companies that prioritize a very limited number of crops with modern or hybrid varieties [21]. In the case of the cultivation of potatoes and other Andean grains, the flow of seeds works with its own dynamics and operates at different scales in local contexts which guarantee the supply of seeds [20].

In the past 10 years, there have been some favorable changes in seed legislation, improving the production, access and use of quality seeds which has gone some way towards strengthening local seed companies in relation to supporting the sustainability of family farming [21]. The renewed legislation in the regulation of specific potato seeds incorporates the declared class that is not subjected to the certification process, so the guarantee of its quality is the responsibility of the producer; additionally, it includes traditional seed categories from native potato biodiversity [31]. However, there are several important challenges to improve the institutional framework of the seed authority and to apply what is indicated in the Seed Law, which states the production and use of quality seeds is of national interest [32].

The limited supply or flow of premium seeds is unfavorable to the sustainability of individual seed producers as well as organized ways to meet local demand for quality seeds. Another aspect that influences the sustainability of the formal sector is the slow development of technology for harvesting and post-harvest aimed at family farmers, which is why some work has to be carried out manually or with rudimentary tools, reducing the efficiency of the process [11].

The Ministry of Agriculture (as the governing body of the agricultural sector), international cooperation and other private initiatives have made great efforts and investment to promote the adoption of quality seed; however, the use of certified seed has had little penetration into informal seed systems, as is currently the case in most developing countries. The rate of use of certified seed of the formal system in Peru is 0.5%; while in China and India it can reach up to 20% [8, 24]. Small farmers in developing and particularly high Andean countries continue to use seed tubers acquired through the informal seed system, that is, produced on the farm or purchased from neighbors or local markets. The formal certification system in Peru is a much smaller percentage of total seeds used (less than 5%), but it is useful to introduce genetic material free of viruses and other key pathogens that affect the quality of the seeds. This explains why in recent years the national average yield has had a significant increase from 8.5 to 15.5 t ha^{-1}, thanks to the growing adoption, access and use of quality seed tubers.

It is possible to improve the access and use of quality seeds by advocating for the capacity building of the official sector (Ministry of Agriculture), extension agents, producers and seed users. Between 2011 and 2015, FAO, together with the Ministry of Agriculture and the National Institute of Agrarian Innovation (INIA), implemented a joint initiative to promote the use of certified seeds of potato, starch corn and quinoa with farmers of family farming systems. The training method through the FFSs facilitated the process and 32 producer organizations managed to integrate into the formal sector for the production of certified seeds. The yields of the three crops indicated above increased by 50%. Agricultural organizations and individual producers that chose to use certified seed managed to increase yields by 64% in potatoes, 56% in quinoa and 31% in starchy corn respectively, a fact that has contributed to improving food security in the high Andean zone [15].

3.5 Agronomic management of potato seed production in family farming systems

Informal potato seed production systems are typically traditional, incorporating components and technologies from the local environment, as well as projects promoted by the public and private sectors. The informal system has its own characteristics and strategies to produce and supply the demand for seeds of local communities. It involves the appropriate seed size, the correct cultivars for the particular niche, utilizing certain production areas (typically in higher mountainous areas to reduce the degeneration of stocks from virus infections), a complex distribution system of seeds and good coordination between regions in Peru according to planting seasons and seed needs.

In family farming systems, the supply of seeds does not represent a great difficulty, applying traditional techniques and not necessarily using certified seed, producers can achieve a multiplication rate of 1:32, supposing that an average seed tuber of a native cultivar generates six stems. However, the seeds can have high rates of infection by bacteria, fungi, viruses and viroids. The huge reserves of native potatoes cannot always be of quality during successive cycles of vegetative propagation [9, 24, 33].

The flow of potato seeds in Peru is characterized by a horizontal and vertical distribution, a fact that contributes to the active exchange of genetic material between communities and farmers [16]. Seed exchange spaces occur at local fairs, religious festivals and community anniversaries, where not only seeds of native varieties are exchanged, but also modern varieties that were incorporated into their production systems; with however, the risk of displacing their local varieties for the best yield and demand in the markets.

3.6 Agronomic management of potato seed production

The main form of multiplication of the potato crop is through clonal propagation; however, this potato seed production system can be laborious, expensive and time consuming to accelerate seed multiplication [6, 9, 33]. Due to the low multiplication rate (generally 1: 6), it takes many years to produce significant quantities of seed to meet the demand. The clonal seed is voluminous, delicate and constitutes a vehicle for the transmission of diseases, increasing the cost of producing, handling and transporting the seed; consequently, seeds represent a high percentage of production costs: 20–25% is typical in developing countries [25].

In family farming systems, the fields for the production of potato seeds should be located between 3,000 to 4,200 masl; in addition to being part of the traditional food safety and quality management strategies. In the case of certified seed production, it is a mandatory requirement and its non-compliance may be grounds for rejection in accordance with the specific regulation of potato seed. Seed produced in cold climates exhibits a broader growth curve and greater productive potential than seed produced in hot climates [16]. In the higher altitude areas, the bitter potato varieties that belong to *S. curtilobum* y *S. juzepczukii* predominate. In the intermediate zones very diverse varieties are cultivated belonging to *S. tuberosum* subsp. *andigena, S. goniocalyx, S. stenostomum* and *S. chaucha*. The areas of lower altitude are characterized by a greater presence of modern or hybrid varieties (*S. tuberosum* subsp. *tuberosum* x *S. tuberosum* subsp. *andigena*).

Fallow systems, locally known as *laymes*, predominate in higher altitude areas. These involve communal lands subdivided into well-defined sectors that are managed under the decision of the local authorities. Rotation commonly begins with potato cultivation during the first year, followed by rest or barley cultivation in the second year [5]. The rest period fluctuates between 3 to 6 years and is characterized by the rotating use of the sectors. This applies mainly to subsistence family farming.

Soil preparation is an important practice given the requirements of the potato plant to facilitate good root development and facilitate complementary agricultural tasks such as hilling and weed management. The use of agricultural machinery and tools in Andean farming currently depends on the location and physiography of the land. In areas with steep slopes, for primary tillage, the ancestral tool called "*chakitaclla*" is commonly used, a manual tool adapted for the difficult geographical conditions of the Andes and consisting of a 1.5-inch wooden arm and metal teeth.

The selection and classification of seeds are practices that consist of selecting healthy potatoes in the first instance, then classifying by size; it is generally customary to classify seed tubers into large, medium, and small size. Due to the volume of crops, their delicate and perishable condition and the possibility of transmitting diseases during harvesting, post-harvest and seed processing, it represents a high percentage of production costs [25].

In traditional systems, sowing is done manually, where 15 to 20 daily wages per hectare are used. The amount of seed varies depending on the size of the seed used. Medium-sized seeds (40 to 60 g) are equivalent to 1800 to 2000 kg of seed per hectare. Some farmers prefer small tubers whose weight does not exceed 60 g, therefore, adjustments are made in the spacing between plants and between rows. With a distance of 20 cm between plants and 80 cm between rows, a population of 37,000 plants per ha is estimated. Whole seeds are used as it is considered that the risk of disease transmission and virus infection is reduced.

The production of seed tubers from potato botanical seed progeny is a technological alternative for obtaining abundant first-generation seed tubers of high phytosanitary and physiological quality in a short period of time. This technology can help reduce production costs and increase the multiplication rate of high-quality seeds, in addition to being kept for five to seven years with a high germination percentage equal to or greater than 70%. However, for family farming systems that mostly use native varieties, the use of botanical seed is not common due to its unstable behavior in terms of risk of segregation [6]. In addition, the true seed management process is a challenge for the environmental conditions of the Peruvian Andes due to sudden changes in temperature, precipitation, drought and other adverse factors. A seedling from true seed when affected by frost for example is totally lost, while a stem from true seed in its early stages can be recovered by a regrowth of the seed tuber.

'Hilling' is a complementary task that consists of accumulating soil in the form of a ridge or ridges at the base of the stem of each plant when the plants reach between 30 to 40 cm in height (or 55 days after sowing), in order to give the plant support, protect tubers from pests and damage by biophysical agents such as low temperatures [6, 26]. The number of hills depends on the characteristics of the soil, the variety, the sowing season and the production system; therefore, in the high Andean areas for some varieties hilling may be one or two ridges [26].

Regarding pest management, farmers integrate agronomic labor, physical, mechanical and chemical control methods. In traditional production systems they are less dependent on external inputs such as industrial pesticides. Agronomic practices are part of traditional strategies in potato production to reduce damage from biotic and agricultural factors such as crop rotation, variety selection, use of good quality seed tubers, sowing density, timing sowing depth, sowing depth, number and timing of hilling and pest management and harvest [6]. A physical control strategy includes the use of barriers with species such as Tarwi (*Lupinus mutabilis* L.) and the use of polyethylene as physical barriers to prevent the entry of *Prennotrypes ssp*. For disease control they mostly use chemical products as in the case of the oomycete *Phytopthora insfestan* (Mont.) de Bary.

To manage weeds in seed fields, farmers combine agricultural practices and mechanical and chemical methods. In family farming systems tillage is an important activity for weed control in potatoes, regardless of region or production system, and includes a wide variety of tactics ranging from simple manual weeding to the use of complicated implements of cultivation [6, 16]. Chemical control is mostly carried out in conventional production systems, but the options for active ingredients of herbicides recommended to control potato weeds are limited; while in traditional production systems it is carried out during the production practices of preparing the land and hilling. The aforementioned activities directly or indirectly involve the concept of integrated weed management where control methods with agronomic work, as well as physical and mechanical work are combined with local knowledge of weed biology [34].

Research in Peru also indicates potentially complex host-pathogen interactions in degenerative diseases. The incidence of the virus could decrease in subsequent generations (that is, not passing from an infected mother plant to all the tubers of the progeny) and that this phenomenon is strongly favored by the production of seeds in high altitude areas. The effectiveness of management practices, such as symptom-free planting selection and clearing, is highly dependent on disease detection.

When the potato crop reaches harvest maturity, farmers carry out the harvests that can be manual or mechanical in some cases, depending on the production system; however, due to the difficult geographical conditions, it is usually manual. The seed tuber storage systems are carried out according to the characteristics of the cultivar, the harvest time, and the dynamics of the seed market. In subsistence family farming systems [14], the seeds are stored indoors or on pallets, covered with straw and muña (*Minthostachys mollis*) or eucalyptus (*Eucalyptus globulus*) leaves. In intermediate family farming systems that are in the process of articulation to the markets, the harvesting and processing of seed consists of the selection, classification, bagging and labeling as long as it is certified seed. For informal systems this process may differ. Seed producers make large piles of tuber seeds and are protected from frost and sunny days with a thick layer of straw. Under these conditions storage can be successful for up to three months.

4. Conclusions

In family farming potato seed systems, informal or non-accredited seed systems predominate over formal systems with small farmers maintaining their native or traditional varieties with seeds selected from their own harvest to guarantee future planting seasons. On the other hand, in formal systems, priority is given to the production of certified seeds of modern varieties of higher categories such as basic, registered and certified -- which are regulated by a certifying body. In this context, in family farming, the use of certified seeds is not a priority or a conditioning factor for potato production; farmers maintain strategies such as the exchange of seeds that since ancient times guarantee the flow of seeds. However, the quality of the seed is not always the best, due to the high levels of genetic degeneration of its seed matter due to the low rotation or refreshment with quality seed. Consequently, the use of low-quality seeds has an impact on yield and are not self-sustaining.

Certified seeds cannot always be considered quality seeds; regulatory and institutional factors such as non-compliance with the quality parameters established in the Seed Law and the specific regulation for each class and category of seeds, adulteration of certification cards and the lack of internal control in institutions and companies that are responsible for generating seeds of the genetic and certified class weaken the seed system, generating distrust in users of quality seeds.

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